have been found, and Mr. W. P. Blake found diatoms in the hot waters of the so-called "geysers" of California and Nevada hot springs.

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Flowers and Insects. I.

CHARLES ROBERTSON.[1]

Delphinium tricorne Michx.—The flower agrees in most respects with D. elatum, as described by Müller.[2]

It is blue, but the exposed parts of the two upper petals which arch over the entrance to the spur are white, forming a sure guide to the nectar. In D. Ajacis, according to Sprengel (702),[3] the upper petals also form the pathfinders by a variation in color. In D. elatum yellow hairs on the lateral petals form the guides, while in D. Consolida pathfinders are wanting (Müller).

The lower petal has disappeared, since its attractive function has been usurped by the sepals. It is unnecessary as a protection to the stamens and pistils, and its presence in the median line would only prevent proper contact with the anthers and stigmas.

The parts whose function has been most imperfectly explained are the two lateral petals. These close over the numerous stamens, completely hiding them, but an entrance to the spur is left between them and the upper petals. When a bee visits the flower, the lateral petals are forced aside, and the under side of the bee's head comes in contact with the

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[1] The following series of papers is intended to give the results of observations begun in 1886, near Carlinville, Ill. It has been necessary at first to pay particular attention to collecting and determining the insects. Accordingly, in case of many flowers I am able at present to give only a list of visitors.

Mr. Cresson has compared my bees with his own type specimens in the collection of the American Entomological Society, except species of Halictus and Andrena. Professor S. W. Williston has kindly identified the Diptera. Mr. C A. Hart and Mr. Samuel Henshaw have aided me in identifying the Coleoptera. Prof. G H. French and Mr. Hart have named a number of Lepidoptera for me. I am also under obligations to Prof. S. A. Forbes for access to the collections and literature of the Illinois State Laboratory of Natural History, and to Prof. William Trelease for access to his valuable index of the bibliography and to much of the special literature of fertilization. Prof. Trelease has also placed at my disposal his unpublished notes on the subject and a collection of insects which he has taken on flowers.

[2] Unless otherwise specified, all references to Müller are to Herman Müller: Fertilization of Flowers. See also on this species Delpino: Ulteriori Osservazioni, and Lubbock: British Wild Flowers.

[3] The numbers in parenthesis after an author's name refer to Thompson's bibliography of the literature of fertilization, which is printed with Müller's Fertilization of Flowers. As this book is the most important source of information on the literature, references are practically thrown away on all who do not have access to it.

anthers and stigmas. The use of these petals seems to be to protect the pollen from intruders. Sprengel saw bees collecting pollen of D. Ajacis, and I have seen a very abundant and useful visitor, Synhalonia speciosa, collecting pollen of D. tricorne, but I am convinced that they behave improperly in so doing. Humble-bees, which are best adapted to fertilize the flowers, never gather pollen. On the other hand, I have seen Andrenidæ trying to collect it, and they were only hindered by the lateral petals. But for these petals most of the pollen would be carried away by little bees which would only visit flowers in the male stage.

The spur of the upper sepal is crumpled, and sometimes fits the spurs of the petals so loosely that its tip is empty and hangs down. Indeed, in one case I found the upper sepal entirely empty, and the spurs of the petals stood in front of its lamina. Delpino (178) regards the spur of the sepal as a protection against the jaws of insects which might attempt to cut a way to the nectar, but both he and Riches[4] found some species of Delphinium to be perforated.

As in D. elatum, the spurs of the petals are entire at the tips and open below into a common cavity. The nectar, therefore, is held in two receptacles, and I have observed that when Bombus and Synhalonia insert their proboscides into the spur, they regularly draw back a little and thrust their tongues in again, evidently to extract the nectar from both petals. I think the double nectary is to favor bees, which are intelligent enough to drain both sides, while butterflies will probably leave one side full. This structure might also be of advantage in case of perforation, since the robber would have to make two holes or leave one side full. The double nectary, however, causes delay, and this seems to be the reason why the nectariferous petals of D. Consolida have developed a common cavity throughout.

D. tricorne agrees with the other species which have been studied in being male in the first stage and in being specially adapted to humble-bees.

The spurs of the petals from the point of insertion to the closed part measure from 7 to 9 mm., and to the tips from 15 to 17 mm., so that a proboscis 7 to 9 mm. long is needed to reach the nectar, and one 15 to 17 mm. long to exhaust it. Only the females of Bombus are flying while the plant blooms. B. Pennsylvanicus, with a tongue 16 to 17 mm. long, is best adapted to suck up all of the honey.

[4] Science Gossip, 1877, 249.

Müller found D. Consolida visited by Bombus hortorum and lapidarius. He also found butterflies, Satyrus and Hesperia, stealing honey, and I have found a still greater number on this plant. The presence of these insects on bee-flowers is always important, since it enables us to understand how many flowers which originally must have been adapted to bees have been modified to suit butterflies. The white-flowered form of this plant might easily become adapted to hawk moths.

Müller found D. elatum visited by Bombus hortorum and Anthophora personata.

On six days between May 4 and 13, I caught the following insects on the flowers. Nos. 4 and 6 are characteristic visitors, while 8–18 are intruders:

Hymenoptera—*Apidæ:* (1) *Bombus virginicus* Oliv. ♀; (2) *B. separatus* Cress. ♀ (11–13)[5]; (3) *B. vagans* Sm. ♀; (4) *B. pennsylvanicus* De G. ♀ (16–17); (5) *Anthophora abrupta* Say ♂ (14); all sucking; (6) *Synhalonia speciosa* Cress. ♂ ♀, s. and c. p.; (7) *S. atriventris* Sm. ♂, s.; (8) *Ceratina dulpa* Say ♀ (5–6) crawling into lower part of spur whence it may reach a little nectar. *Andrenidæ:* (9) *Agapostemon radiatus* Say ♀; (10) Halictus sp. ♀, both trying to collect pollen.

Lepidoptera—*Rhopalocera:* (11) *Danais archippus* F.; (12) *Papilio asterias* F.; (13) *P. troilus* L.; (14) *P. turnus* L.; (15) *Colias philodice* Godt.; (16) *Pamphila zabulon* Bd.-Lec.; (17) *Eudamus tityrus* F. *Sphingidæ:* (18) *Deilephila lineata* F.

Nuphar advena Ait.—On the first day the anthers are closed, and are crowded in a compact mass under the edges of the broad stigma. Their fleshy tips keep them from being gnawed by beetles. The petals also protect the lower anthers from gnawing-insects, and secrete nectar on their outer faces. At this time the stigma is receptive, and the flower is therefore proterogynous. The yellow sepals separate so as to leave a triangular opening over the stigma, so narrow that insects can not enter the flower without crawling over the stigmatic surface.

On the second and one or two succeeding days the anthers are dehiscent. The sepals then are often so widely separated that insects are no longer required to come in contact with the stigma.

[5] The numbers after an insect's name indicate the length of the proboscis in millimetres.

In Illinois in August, and in Florida in February, I found the flowers visited by the same species of insects, *Halictus pectoralis* Sm. ♀ (Andrenidæ), and *Helophilus divisus* Loew (Syrphidæ). In Florida I also found it visited by a fly, *Notiphila* sp. (Ephydridæ), and a beetle, *Donacia piscatrix* Lac. (Chrysomelidæ). The beetles were abundant on the older flowers, where they were pairing, the females gnawing the petals and anthers. I tried to catch the visitors by holding my net over the flowers and shaking the stalks, which only made the bees lie more closely, and for awhile I thought visitors were very scarce. Finally, I picked many flowers, and, bending back the sepals, found an Halictus under the petals of most of them, especially the new flowers. All of the bees taken on new flowers were well dusted with pollen from older flowers.

At Madison, Wisconsin, Prof. Trelease (MS. notes) also found it visited by Halictus pectoralis and Donacia piscatrix.

Sprengel (702) found N. luteum visited by beetles of the genus Meligethes. Müller also found it visited by Meligethes, and by Onesia floralis (Muscidæ) and Donacia dentata.

Delpino (178) regards N. luteum as adapted to beetles, but I find no evidence of such adaptation in N. advena; the beetles which occur I regard as worse than useless. However, beetles of the genus Donacia are very fond of the flowers of Nuphar, since they were observed on them by Müller in Germany, by Trelease in Wisconsin, and by me in Florida.

Figures of N. luteum in Hooker's edition of Le Maout and Decaisne's Botany, 208, and in Sprengel, Pl. XXIII, indicate fairly well the male stage of N. advena. I see nothing to lead insects to touch the stigma when the flower is so widely expanded. Indeed, Sprengel says: "Bei der Nymphæa hingegen ist es ein blotzer Zufall, das die Blumenkäfer den Antherenstaub auf das Stigma schleppen," and he regards this as an explanation of the large size of the stigma. Pollination seems so uncertain in such a flower as to incline one to doubt whether it is intended to occur when the flower is so widely expanded.

Nymphæa tuberosa Paine.—In Southern Illinois this plant blooms from May until October. The flowers open in the morning sun and close in the afternoon.

On the first day the flowers are not widely expanded, looking like buds at a distance, and the first stage is likely to be overlooked. The petals stand close together, leaving but

a narrow entrance. The stamens stand in a compact circle close to the petals, and the anthers are indehiscent. The filaments vary from the outer, which are long and broad, to the innermost, which are short and slender. The claw-like scales which surround the concave stigma form with it a little bowl, which holds a large drop of water. At this time the stigmatic papillæ are well developed, and the flower is evidently in the female stage.

On the second morning the water has disappeared from the stigmatic basin, and the papillæ look dry and shrivelled. The claw-like scales are curled in strongly over the stigma, and the inner stamens, which are now dehiscent, have fallen over it, so as completely to hide it. The outer stamens are turned outward, and the petals are widely expanded.

Of eight flowers which were marked, four opened on three days and four on four days. One of the latter had some anthers still closed at noon of the fourth day, promising to open again on the fifth. The flowers are therefore female on the first day and male for two or three days after. It follows that, when about the same number of new flowers open daily, there will be two or hree times as many in the male as in the female stage.

All of the insects which I saw on the flowers were in search of pollen, which the numerous stamens yield in abundance. Insects coming from the old flowers drop into the new ones, and plunge into the stigmatic basin. If, in their attempts to escape, they trust their weight to the inner stamens, these bend so suddenly as to throw them again into the water. If the insect does not drop into the stigmatic basin, but lights on the stamens, the slender filaments act like the lip of Calopogon and let him down upon the stigma.

The water on the stigma seems to be intended to loosen the pollen from the scopæ of bees which have been collecting it on the older flowers. I have not discovered any sweet taste in the water, nor have I seen insects attracted by it. Moreover, it seems to be present in too great quantity for the purpose of nectar. Indeed, when insects are thrown back repeatedly into it, they may be drowned. I have seen Agapostemon radiatus and Halictus occcidentalis drowned in the same basin.[6]

If my interpretation is correct, the flower is remarkable

[6] A. Bacon (Torr. Bull. V, 51) found dead insects in flowers of N. odorata, which he supposes were captured by the flower closing up. Delpino (178) also found dead insects in N. alba, and considers their death as a result of the heavy odor of the flower. Planchon (Flore des serres et des jardins, 1850) thinks it a result of the accumulation of carbonic acid in the bottom of the flower

for having perfected a proterogynous condition, although visited exclusively for pollen. Even when nectar is present, many insects in search of pollen only visit dichogamous flowers in the male stage. We have observed that most of the flowers are discharging pollen, so that insects drop carelessly into them and are evidently surprised when they find themselve in the stigmatic basin of a new flower. Attracted by the abundant stamens, they do not discover their mistake before they touch the stigma. However, I have sometimes seen Halictus pectoralis turn away from a new flower into which it was about to drop, and fly to an old one.

On ten days between May 22 and September 18, I took the following insects on the flowers: Hymenoptera—*Andrenidæ:* (1) Agapostemon radiatus Say ♀, c. p., ab., sometimes drowned; (2) A. nigricornis F. ♀, c. p., ab.; (3–4) Halictus spp., ♀, c. p.; (5) H. pectoralis Sm. ♀, c. p., ab.: (6) H. occidentalis Cress. ♀, c. p.. sometimes downed; (7) H. coriaceus Sm. ♀, c. p. do.; (8) Prosopis sp. ♀, e. p.

Diptera—*Syrphidæ:* (9) Helophilus divisus Lw. e. p., ab.; (10) H. latifrons Lw., e. p. *Bombylidæ:* (11) Sparnopolius fulvus Wied.

Coleoptera—*Rhipiphoridæ:* (12) Rhipiphorus limbatus F., drowned.

Nymphæa odorata L.—The flower resembles N. tuberosa, and is likewise female in the first stage. In Florida, in February, I have seen it visited by Halictus pectoralis Sm. ♀.

Delpino (178) regards Nymphæa as specially adapted to beetles. He states that Piccioli found N. alba abundantly visited by Donacia.

Dicentra Cucullaria DC.—The flower is figured and its mechanism described by Hildebrand (358). A peculiar interest surrounds it from the fact that its time of blooming is correlated with the appearance of long-tongued bees, and in my neighborhood it is the first flower adapted to them. In April, 1886, the first open flower was observed on the 7th, with no visitor. April 9, I found hive-bees collecting pollen and Papilio ajax sucking. April 11, hive-bees were collecting pollen, Bombylius, butterflies and the first humble-bees were sucking. On the 12th, humble-bees were present in considerable numbers for the first time, so that it required six days for the proper insect relations to become established.

The two inner petals are united over the anthers, protect-

ing them from insects which are in search of pollen, so that the flowers are only adapted to be visited for honey. But the hive-bee visits the flower only for pollen, and I have seen no better illustration of its ingenuity than its success in gathering it. With its head it pushes aside the inner petals, partly separating them, while it removes the pollen with its front feet.

The pendulous position of the flowers makes them inconvenient for all visitors except bees (and Bombylius), but butterflies sometimes hang under the flowers and steal some of the nectar.

The nectar is secreted by two long processes of the middle stamens, and rises to the tip of the spur. A proboscis about 8 mm. long is necessary to reach it, and one 12½ to 14 mm. to obtain all of it. The females, which have longer tongues than the males and workers, are the only individuals of Bombus which fly while this plant is in bloom, and since the shortest-tongued of them can easily reach the nectar, it is strange that any should ever be guilty of cutting holes in the flowers. I have seen many individuals of four species sucking, but never perforating. However, the flowers are sometimes perforated by humble-bees (?), according to Leggett, Bailey, Stone and Merriam[7]. One observer states that humble-bees made the holes, and that honey-bees were sucking. The honey-bee's tongue is only 6 mm. long, and can hardly reach any of the nectar, and although I have seen this bee collecting pollen very often, I have never seen it sucking. His honey-bee was evidently a Synhalonia.

Observed on ten days, between April 9 and 30. Nos. 2–12 are proper visitors, the rest intruders. Hymenoptera–*Apidæ:* (1) Apis mellifica L. ☿, c. p.; (2) Bombus virginicus Oliv. ♀; (3) B. separatus Cress. ♀; (4) B. vagans Sm. ♀; (5) B. pennsylvanicus DeG. ♀; (6) Anthophora ursina Cress. ♂; (7) Habropoda floridana Sm. ♂; (8) Synhalonia atriventris Sm. ♂; (9) S. honesta Cress. ♂ ♀; (10) Osmia latitarsis Cress. ♂; (11) O. montana Cress. ♂; (12) O. lignaria Say ♂ ♀.

Diptera–*Bombylidæ:* (13) Bombylius fratellus Wied., sometimes on cold days the exclusive visitor.

Lepidotera–*Rhopalocera:* (14) Danais archippus F.; (15) Pyrameis atalanta L.; (16) Papilio ajax L.; (17) Pieris rapae L.; (18) Nisoniades martialis Scud., all sucking, except 1.

[7] See Pammel: Trans. St. Louis Acad. Sci., v. p. 274.